ASD
APOLLO SYSTEMS DEPARTMENT
GENERAL ELECTRIC

NASA CR: 160216

HOUSTON, TEXAS TECHNICAL INFORMATION RELEASE | TIR 741-MED-4008

FROM	TO		
D. G. Fitzjerrell	J. A. Rummel, Ph.D./DB6		
DATE: 3/29/74	WORK ORDER REF: DM-110T	WORK STATEMENT PARA: NAS9-12932	REFERENCE:

SUBJECT: User's Instructions for the GE Cardiovascular Model to Simulate LBNP and Tilt Experiments (with Graphic Capabilities)

(NASA-CR-160216) USER'S INSTRUCTIONS FOR THE GE CARDIOVASCULAR MODEL TO SIMULATE LBNP AND TILT EXPERIMENTS, WITH GRAPHIC CAPABILITIES (General Electric Co.) 33 p HC A03/MF A01 CSCL 06P G3/52

N79-25732

Unclas 22234

The present form of this cardiovascular model simulates both 1-g and zero-g LBNP experiments and tilt experiments. In addition, the model simulates LBNP experiments at any body angle. The model is currently accessible on the Univac 1110 Time-Shared System in an interactive operational mode. Model output may be in tabular form and/or graphic form. The graphic capabilities are programmed for the Tektronix 4010 graphics terminal and the Univac 1110.

D. G. Fitzjerrell

Attachment
/db

CONCURRENCES

Counterpart:

Medical Projects Unit Manager: RCCroston

Engrg. & Advanced Programs Subsection Mgr. CWFulcher

DISTRIBUTION: NASA/JSC: Retha Shirkey/ JM6 (1979 distribution)

NASA/JSC: G.Hoffler,M.D., A.Nicogossian,M.D., C.Sawin, Ph.D., M.Buderer,Ph.D., P.Schachter,Ph.D.

GE/AGS: D.J.Grounds, R.F.Hassell, J.I. Leonard, V.J. Marks, G.T.Archer, CPFile

ASD 4028

PROGRAM DESCRIPTION

A. IDENTIFICATION

Program Name - G. E. Cardiovascular LBNP Model (Univac 1110 Version)

Bioengineer Contact - D. G. Fitzjerrell

Programmer's Name - V. J. Marks, GE/JSC, Houst

Date of Issue - March 29, 1974

B. GENERAL DESCRIPTION

A mathematical model and digital computer simulation of the human cardiovascular system and its controls were developed to simulate responses to lower body negative pressure (LBNP) and tilt experiments. The purpose of the model is to provide a method to analyze cardiovascular control hypotheses which cannot be easily tested in an animal or human or in a spaceflight environment.

C. USAGE AND RESTRICTIONS

Machine and Compiler Required - Univac 1110 TSS and Fortran V

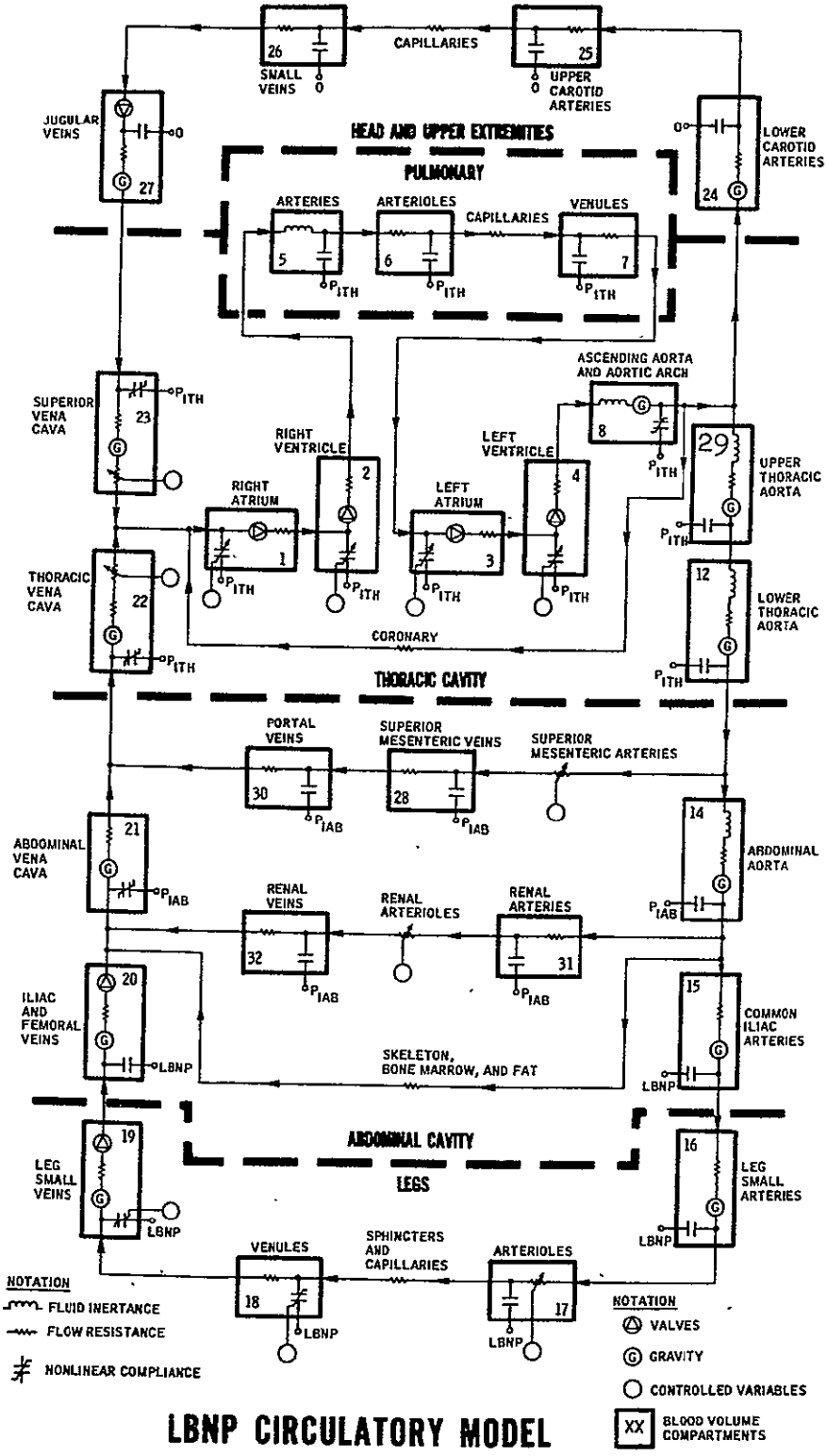
Peripheral Equipment Required - Magnetic Tape
- Time-Sharing Terminal

D. PARTICULAR DESCRIPTION

Basic Equations Used and Derivations - See TIR No. 741-MED-2010 (Exercise Model)

Definition of Terms Used - See Table 1.

Detailed Description - Equations describing pulsatile blood flows, pressures, and volumes for 28 model sections of the cardiovascular circulatory model are solved. The circulatory system model, Figure 1, is combined with models of the controlling systems to form a dynamic model to simulate responses to LBNP and tilt. Other characteristics of the combined model include gravity effects, venous tone, venous valves, and intrathoracic and intra-abdominal pressure effects.



LBNP CIRCULATORY MODEL

FIGURE 1

E. DESCRIPTION OF INPUT

(1) Contact V. J. Marks, GE/JSC, Houston, to obtain Univac 1110 sign-on procedures and authorization codes.

(2) The first inquiry made by the interactive program is for the selection of either an LBNP or Tilt Experiment.

(3) The responses to conversational output of the program allows the user to change the standard set of initialization data shown in Table 1. If this is desired, the user enters the appropriate index code and new value for each variable as directed. When no more changes are to be requested, zero is entered. If a tilt experiment is being simulated, the value of the angle in degrees, measured positive clockwise from horizontal, should be entered with the index of 575. If graphic output of pressure waveform data is wanted for a given two second interval, the end time should be entered in seconds with an index of 598. Other typical inputs include LBNP simulation protocol (elements 541-560) and print interval (element 599).

F. DESCRIPTION OF OUTPUT

(1) If the graphic output option is selected,a graphics terminal is required. (The graphics in this program are written for the Tektronix 4010). This option suppresses the initial printout of tabular data. A plotted output is generated as it is computed. As computation proceeds, the output variables selected are buffered and may be outputed in tabular or graphic form as selected.

(2) Conversational output of the program will ask the user if he wishes to change the standard terminal output list of variables. If so, the user enters the appropriate column number and index code for each variable as directed by the conversational output of the program. The standard set of output variables consists of time and 8 dependent variables which are output each print interval and averaged for the last five heart beats. The selected standard variables are as follows:

1 Simulation Time (sec)

2 Heart Rate (beats/min)

3 Cardiac Output (liters/min)

4 Stroke Volume (liters)

5 Mean Blood Pressure (mm Hg)

6 Systolic Blood Pressure (mm Hg)

(Cont'd)

7 Diastolic Blood Pressure (mm Hg)

8 Lower Body Negative Pressure (mm Hg) or Tilt angle, (Deg) if selected.

9 Total Blood Volume in Legs (ml)

If graphic output option is selected, conversational operation of the program will direct the input of time intervals and start and stop times. (See example page 29). The number of time intervals (3-5) specifies how many increments to divide the time scale. The default option for stop and start times includes the total simulation run. Location and variable limits information for each plotted variable selected is then solicited in a similar manner. It should be noted that each entry must be properly positioned as shown in the example. Each location specified (1-6) directs the location in which the variable will be plotted (see example page 29). An additional option available is plotted output of pressure waveform data. This data is stored at rate of 90 points per second for the two seconds preceding the time entered for element 598. The volume compartments for which pressure waveforms plots may be selected are as follows:

Element	Mnemonic	Volume Compartment
204	PLV	Left Ventricle
208	PAA	Aortic Arch
212	PLTA	Lower Thoracic Aorta
211	PUTA	Upper Thoracic Aorta
214	PLABA	Abdominal Aorta
215	PCILL	Common Iliac Artery
224	PLØC	Lower Carotid Arteries
231	PRENA	Renal Arteries

H. INDEPENDENT SUBROUTINES

CVS	Pulsatile Circulatory Model
CONTRL	Cardiovascular Controlling Systems
ALGO	Integration Algorithm
XIO	Conversational Input/Output
BLKDAT	Initialization Data
TEKTRONIX PLOT PACKAGE	

I. COMPUTER PROGRAM LISTING AND EXAMPLE OUTPUT

(Attached)

TABLE 1

DEFINITIONS

ELEMENT NO.	MNEMONIC	DEFINITION	CONSTANT OR INITIAL VALUE	UNITS
1	X(1)	Stressed Vol., RT. Atrium	89.9	ml
2	X(2)	" " , RT. Ventricle	215.8	"
3	X(3)	" " , Left Atrium	38.7	"
4	X(4)	" " , Left Ventricle	218.0	"
5	X(5)	" " , Pulmonary Arteries	7.7	"
6	X(6)	" " , " Arterioles	10.6	"
7	X(7)	" " , " Venules	27.4	"
8	X(8)	" " , Aortic Arch	23.9	"
9	X(9)	Inertance Integral	0.0	-
10	X(10)	Integral of Aortic Arch Pressure/Beat	0.0	mmHg-sec
11	X(11)	Inertance Integral	0.0	-
12	X(12)	Stressed Vol., Thoracic Aorta	23.6	ml
13	X(13)	Integral of Carotid Pressure/Beat	0.0	mmHg-sec
14	X(14)	Stressed Vol., Abdominal Aorta	16.2	ml
15	X(15)	Stressed Vol., Common Iliac Arteries	62.3	"
16	X(16)	" " , Legs Small Arteries	62.4	"
17	X(17)	" " , Legs Arterioles	4.1	"
18	X(18)	" " , Legs Venules	126.0	"
19	X(19)	" " , Legs Small Veins	205.0	"
20	X(20)	" " , Femoral Veins	41.0	"
21	X(21)	Total Vol., Abdominal Vena Cava	355.2	"
22	X(22)	Total Vol., Thoracic Vena Cava	253.5	"
23	X(23)	Total Vol., Superior Vena Cava	36.4	"
24	X(24)	Stressed Vol., Lower Carotid Arteries	23.5	"
25	X(25)	" " , Upper Carotid Arteries	31.2	"
26	X(26)	" " , Head Small Veins	63.4	"
27	X(27)	" " , Jugular Veins	3.1	"
28	X(28)	" " , Superior Mesenteric Veins	254.2	"
29	X(29)	Stressed Vol., Upper Thoracic Aorta	30.0	"
30	X(30)	Stressed Vol., Portal Veins	120.7	"
31	X(31)	" " , Renal Arteries	17.1	"
32	X(32)	" " , Renal Veins	43.7	"
33	X(33)	Integral of Left Vent. Flow/Beat	0.0	"
34	X(34)	Inertance Integral	0.0	-
35	X(35)	" "	0.0	-
36	X(36)	" "	0.0	-
37	X(37)	Integral of Upper Thoracic Aortic Pressure	0.0	mmHg-sec.
38	X(38)	Not Used	-	
39	X(39)	"	-	-
40	X(40)	"	-	-

ELEMENT NO.	MNEMONIC	DEFINITION	CONSTANT OR INITIAL VALUE	UNITS
41	X(41)	Not Used	-	-
42	X(42)	" "	-	-
43	X(43)	" "	-	-
44	X(44)	" "	-	-
45	X(45)	" "	-	-
46	X(46)	" "	-	-
47	X(47)	" "	-	-
48	X(48)	" "	-	-
49	X(49)	" "	-	-
50	X(50)	" "	-	-
51 - 100				
101	QRA	Flow from RT. Atrium	Computed	ml/sec
102	QRV	" " RT. Ventricle	Variable	"
103	QLA	" " Left Atrium	"	"
104	QLV	" " " Ventricle	"	"
105	QPA	" " Pulmonary Arteries	"	"
106	QPC	" " Pulmonary Arterioles	"	"
107	QPV	" " " Venules	"	"
108	QAA	" " Aortic Arch	"	"
109		Not Used		
110		" "		
111	QUTA	Flow From Upper Thoracic Aorta	Computed	ml/sec
112	QLTA	Flow from Lower Thoracic Aorta	Variable	"
113		Not Used		
114	QLABA	Flow from Abdominal Aorta	"	"
115	QCILL	Flow from Common Iliac Arteries	"	"
116	QLGSA	" " Leg Small Arteries	"	"
117		Not Used		
118	QLGCAP	Flow from Leg Arterioles	"	"
119	QLGVE	" " Leg Venules	"	"
120	QLGSV	" " Leg Small Veins	"	"
121	QFEV	" " Femoral Veins	"	"
122	QABVC	" " Abdominal Vena Cava	"	"
123	QTHVC	" " Thoracic " "	"	"
124	QSPVC	" " Superior Vena Cava	"	"
125	QLOC	Flow to Lower Carotid Arteries	"	"
126	QUPC	" " Upper " "	"	"
127	QHCAP	" from Upper Carotid Arteries	"	"
128	QHSV	" from Head Small Veins	"	"
129	QJV	" from Jugular Veins	"	"
130	QCØR	Coronary Blood Flow	"	"

ELEMENT NO.	MNEMONIC	DEFINITION	CONSTANT OR INITIAL VALUE	UNITS
131	QCSMA	Flow to Superior Mesenteric Veins	Computed	ml/sec
132		Not Used	Variable	"
133	QCSMV	Flow from Superior Mesenteric Veins	"	"
134	QPØV	" " Portal Veins	"	"
135		Not Used	"	"
136	QRENA	Flow to Renal Arteries	"	"
137	QRALE	Flow from Renal Arteries	"	"
138	QRENV	" " Renal Vein	"	"
139	QRET	Flow to RT. Atrium	"	"
140	QD(1)	Not Used		
141		Not Used		
142		Not Used		
143		Not Used		
144		Not Used		
145		Not Used		
146		Not Used		
147		Not Used		
148		Not Used		
149	QD(10)	Not Used		
150	QSKB	Flow Through Skeleton, Bone Marrow, and Fat	Computed Variable	ml/sec "
151	CRA	Compliance, Right Atrium	"	ml/mmHg
152	CRV	" , Right Ventricle	"	"
153	CLA	" , Left Atrium	"	"
154	CLV	" , Left Ventricle	"	"
155	CPA	" , Pulmonary Arteries	1.2	ml/mmHg
156	CPC	" " Arterioles	1.7	"
157	CPV	" " Venules	5.3	"
158	CAA	" , Aortic Arch	0.3	
159		Not Used		
160		Not Used		
161	CUTA	Upper Thoracic Aorta	0.4	
162	CLTA	Lower Thoracic Aorta	0.4	
163		Not Used		
164	CLABA	Abdominal Aorta	0.21	
165	CCILL	Compliance, Common Iliac Arteries	0.8	"
166	CLGSA	" , Leg Small Arteries	0.8	"
167	CLGAR	" , Leg Arterioles	0.3	"
168	CLGVE	" , Leg Venules	3.956	"
169	CLGSV	" , Leg Small Veins	3.14	"
170	CFEV	" , Leg Femoral Veins	0.2	"
171		Temporary Storage		
172		" "		
173		" "		
174	CLØC	Compliance, Lower Carotid Arteries	0.3	"
175	CUPC	" , Upper " "	0.3996	"
176	CHSV	" , Head Small Veins	5.3	"
177	CJV	" , Jugular Veins	0.9058	"
178	CCSMV	" , Superior Mesenteric Veins	9.59	"
179		Not Used	-	"
180	CPØV	" , Portal Veins	6.047	"

ELEMENT NO.	MNEMONIC	DEFINITION	CONSTANT OR INITIAL VALUE	UNITS
181	CRENA	Compliance, Renal Arteries	0.2224	
182	CRENV	" , Renal Veins	2.517	
183	CD(1)	Not Used		
184		"		
185		"		
186		"		
187		"		
188		"		
189		"		
190		"		
191		"		
192		"		
193		"		
194		"		
195		"		
196		"		
197		"		
198		"		
199		"		
200	CD(18)	"		

CALCULATED VARIABLES FOR EACH VOLUME COMPARTMENT

ELEMENT NO.	PRESSURE (mm Hg)			PRESSURE DUE TO GRAVITY		EXTERNAL PRESSURE		VOLUME COMPARTMENT
201	PRA	321	V(1)	421	PG(1)	455	PEXT(1)	RT. Atrium
202	PRV	322	V(2)	422	PG(2)	456	PEXT(2)	RT. Ventricle
203	PLA	323	V(3)	423	PG(3)	457	PEXT(3)	Left Atrium
204	PLV	324	V(4)	424	PG(4)	458	PEXT(4)	Left Ventricle
205	PPA	325	V(5)	425	PG(5)	459	PEXT(5)	Pulmonary Arteries
206	PPC	326	V(6)	426	PG(6)	460	PEXT(6)	Pulmonary Arterioles
207	PPV	327	V(7)	427	PG(7)	461	PEXT(7)	Pulmonary Veins
208	PAA	328	V(8)	428	PG(8)	462	PEXT(8)	Aortic Arch
209	Temporary Storage			429	PG(9)	463	PEXT(9)	
210	"	"		430	PG(10)	464	PEXT(10)	
211	PUTA	"		431	PG(11)	465	PEXT(11)	Upper Thor.Aorta
212	PLTA	332	V(12)	432	PG(12)	466	PEXT(12)	Lower Thor.Aorta
213	Temporary Storage			433	PG(13)	467	PEXT(13)	
214	PLABA	334	V(14)	434	PG(14)	468	PEXT(14)	Abdominal Aorta
215	PCILL	335	V(15)	435	PG(15)	469	PEXT(15)	Common Iliac Artery
216	PLGSA	336	V(16)	436	PG(16)	470	PEXT(16)	Leg Small Arteries
217	PLGAR	337	V(17)	437	PG(17)	471	PEXT(17)	Leg Arterioles
218	PLGVE	338	V(18)	438	PG(18)	472	PEXT(18)	Leg Veins
219	PLGSV	339	V(19)	439	PG(19)	473	PEXT(19)	Leg Small Veins
220	PFEV	340	V(20)	440	PG(20)	474	PEXT(20)	Femoral Veins
221	PABVC	341	V(21)	441	PG(21)	475	PEXT(21)	Abdominal Vena Cava
222	PTHVC	342	V(22)	442	PG(22)	476	PEXT(22)	Thoracic Vena Cava
223	PSPVC	343	V(23)	443	PG(23)	477	PEXT(23)	Superior Vena Cava
224	PLØG	344	V(24)	444	PG(24)	478	PEXT(24)	Lower Carotid Arteries
225	PUPC	345	V(25)	445	PG(25)	479	PEXT(25)	Upper Carotid Arteries
226	PHSV	346	V(26)	446	PG(26)	480	PEXT(26)	Head Small Veins
227	PJV	347	V(27)	447	PG(27)	481	PEXT(27)	Jugular Veins
228	PCSMV	348	V(28)	448	PG(28)	482	PEXT(28)	Superior Mesenteric Veins
229	Not Used	349	Not Used	449	Not Used	483	Not Used	
230	PPØV	350	V(30)	450	PG(30)	484	PEXT(30)	Portal Veins

CALCULATED VARIABLES FOR EACH VOLUME COMPARTMENT

ELEMENT NO.	PRESSURE (mm Hg)	TOTAL VOLUME (ml)	PRESSURE DUE TO GRAVITY	EXTERNAL PRESSURE	VOLUME COMPARTMENT
231	PRENA	351 V(31)	451 PG(31)	485 PEXT(31)	Renal Arteries
232	PRENV	352 V(32)	452 PG(32)	486 PEXT(32)	Renal Veins
233	PD(1) Mean Upper Thoracic Aortic Pressure				
234	Not Used		453 - 454 Not Used		
235	Not Used	353 - 368 Not Used			
236	" "	369 - V(49) Blood Volume Command = 5000.0 ml			
237	" "	370 - V(50) Total Blood Volume = 5000.0 ml			
238	" "				
239	" "				
240	" "				
241	" "				
242	" "				
243	" "				
244	" "				
245	" "				
246	" "				
247	" "				
248	" "				
249	PM Mean Arterial Pressure			90.0	mmHg
250	PMC Mean Carotid Arterial Pressure			90.0	mmHg

ELEMENT NO.	MNEMONIC	DEFINITION	CONSTANT OR INITIAL VALUE	UNITS
251	RRA	RT. Atrium Valve Resistance	0.007508	mmHg/ml/se
252	RRV	RT. Ventricle Valve Resistance	0.007508	"
253	RMV	Left Atrium Valve	0.007508	"
254	RAV	Left Ventricle Valve	0.008634	"
255	RPA	Pulmonary Arterioles	0.01502	"
256	RPC	Pulmonary Capillaries	0.05255	"
257	RPV	Pulmonary Venules	0.01502	"
258		Not Used		
259		Not Used		
260	RUTA	Upper Thoracic Aorta	0.04	
261	RLTA	Lower Thoracic Aorta	0.04	"
262		Not Used	0.0	
263	RLABA	Abdominal Aorta	0.03	"
264	RCILL	Common Iliac Arteries	0.03	"
265	RLGSA	Leg Small Arteries	0.03003	"
266	RLGAR	Leg Arterioles	4.505	"
267	RLGCAP	Leg Capillaries	0.4505	"
268	RLGVE	Leg Venules	0.07508	"
269	RLGSV	Leg Small Veins	0.07508	"
270	RFEV	Femoral Veins	0.02102	"

ELEMENT NO.	MNEMONIC	DEFINITION	CONSTANT OR INITIAL VALUE	UNITS
271	RABVC	Abdominal Vena Cava	0.007380	mmHg/ml/se
272	RTHVC	Thoracic Vena Cava	0.007508	"
273	RSPVC	Superior Vena Cava	0.01502	"
274	RLØC	Lower Carotid Arteries	0.02252	"
275	RUPC	Upper Carotid Arteries	0.03378	"
276	RHCAP	Head Capillaries	3.431	"
277	RHSV	Head Small Veins	0.3754	"
278	RJV	Jugular Veins	0.004302	"
279	RCØR	Coronary	15.390	"
280	RCSMA	Superior Mesenteric Arteries	1.9744745	"
281		Not Used		"
282	RCSMV	Superior Mesenteric Veins	0.2252	"
283	RPOV	Portal Veins	0.5255	"
284		Not Used		"
285	RRENA	Renal Arteries	0.01502	"
286	RRALE	Renal Arterioles	0.45045	"
287	RREFF	Efferent Arterioles	2.744	"
288	RRENV	Renal Veins	0.6494	"
289	RD(1)	Not Used		
290		" "		
291		Not Used		
292		" "		
293		" "		
294		" "		
295		" "		
296		" "		
297		" "		
298		" "		
299	RD(11)	" "		
300	RSKB	Skeleton and Fat	5.150	"
301	FLPA	Inertance, Pulmonary Arteries	0.0007508	$mmHg/ml/sec^2$
302	FLAA	" , Aortic Arch	0.004	"
303		Not Used		
304		" "		
305	FLUTA	Inertance, Upper Thoracic Aorta	0.004	
306	FLLTA	Inertance, Thoracic Aorta	0.004	"
307		Not Used		
308	FLLABA	Inertance, Abdominal Aorta	0.004	"
309		Not Used		"
310 - 320		Not Used		

UNSTRESSED VOLUMES

ELEMENT NO.	MNEMONIC	DEFINITION	CONSTANT OR INITIAL VALUE	UNITS
371	VU(1)	Rt. Atrium	30.0	ml
372	VU(2)	Rt. Ventricle	0.0	"
373	VU(3)	Left Atrium	30.0	"
374	VU(4)	Left Ventricle	0.0	"
375	VU(5)	Pulmonary Arteries	85.0	"
376	VU(6)	Pulmonary Arterioles	15.0	"
377	VU(7)	Pulmonary Veins	400.0	"
378	VU(8)	Aortic Arch	61.6	
379	VU(9)	Not Used		
380	VU(10)	" "		
381	VU(11)	" "		
382	VU(12)	Thoracic Aorta	90.5	
383	VU(13)	Not Used		
384	VU(14)	Abdominal Aorta	43.5	
385	VU(15)	Common Iliac Arteries	5.194	"
386	VU(16)	Leg Small Arteries	30.0	"
387	VU(17)	Leg Arterioles	30.0	"
388	VU(18)	Leg Venules	0.0	"
389	VU(19)	Leg Small Veins	0.0	"
390	VU(20)	Femoral Veins	0.0	"
391	VU(21)	Not Used		
392	VU(22)	" "		
393	VU(23)	" "		
394	VU(24)	Lower Carotid Arteries	50.0	"
395	VU(25)	Upper Carotid Arteries	50.0	"
396	VU(26)	Head Small Veins	509.0	"
397	VU(27)	Jugular Veins	28.0	"
398	VU(28)	Superior Mesenteric Veins	562.0	"
399	VU(29)	Not Used		"
400	VU(30)	Portal Veins	375.0	"
401	VU(31)	Renal Arteries	50.0	"
402	VU(32)	Renal Veins	150.0	"
403 - 420		Not Used		
487	E(1)	Right Atrial Elastance	Computed Variable	mmHg/ml
488	E(2)	Right Ventricle Elastance	" "	"
489	E(3)	Left Atrial Elastance	" "	"
490	E(4)	Left Ventricle Elastance	" "	"
491	PRN	Pressure Set Point	88.0	mmHg
492	ABIAS	Abdominal Vena Cava Compliance Curve Bias	2.55	-
493	TBIAS	Thoracic Vena Cava Compliance Curve Bias	3.6	-
494	TTHAZ	Tilt Down Time	9999.	-
495	TMODEL	Tilt Exp. Select	0.	
496	SPACE(1)	Not Used		
497	SPACE(2)	" "	0.0	mmHg
498	ECBV	Effective Circulating Blood Volume	Computed Variable	ml
499	PTIS	PTIS-Tissue Press. in Legs	2.0	mmHg
500	BSLG	Blood Shifted from Legs	0.	mmHg

ELEMENT NO.	MNEMONIC	DEFINITION	CONSTANT OR INITIAL VALUE	UNITS
501	Z(1)	Length of Vascular Segment	0.0	cm
502	Z(2)	"	0.0	"
503	Z(3)	"	0.0	"
504	Z(4)	"	0.0	"
505	Z(5)	"	0.0	"
506	Z(6)	"	0.0	"
507	Z(7)	"	0.0	"
508	Z(8)	"	-7.0	"
509	Z(9)	"	0.0	"
510	Z(10)	"	0.0	"
511	Z(11)	"	0.0	"
512	Z(12)	"	10.0	"
513	Z(13)	"	10.0	"
514	Z(14)	"	16.0	"
515	Z(15)	"	6.0	"
516	Z(16)	"	33.0	"
517	Z(17)	"	0.0	"
518	Z(18)	"	0.0	"
519	Z(19)	"	33.0	"
520	Z(20)	"	14.0	"
521	Z(21)	"	14.0	"
522	Z(22)	"	2.0	"
523	Z(23)	"	-7.0	"
524	Z(24)	"	-14.0	"
525	Z(25)	"	0.0	"
526	Z(26)	"	0.0	"
527	Z(27)	"	-14.0	"
528	Z(28)	"	0.0	"
529	Z(29)	"	0.0	"
530	Z(30)	"	0.0	"
531	Z(31)	"	0.0	"
532	Z(32)	"	0.0	"
533	Z(33)	"	0.0	"
534	Z(34)	"	0.0	"
535	Z(35)	"	0.0	"
536	Z(36)	"	0.0	"
537	Z(37)	"	0.0	"
538	Z(38)	"	0.0	"
539	Z(39)	"	0.0	"
540	Z(40)	"	0.0	"
541	WK(1)	Time(Sec), LBNP Steps	0.0	Sec.
542	WK(2)	" "	0.0	mmHg
543	WK(3)	" "	60.0	Sec.
544	WK(4)	" "	-8.0	mmHg
545	WK(5)	" "	120.0	Sec.
546	WK(6)	" "	-16.0	mmHg
547	WK(7)	" "	180.0	Sec.
548	WK(8)	" "	-30.0	mmHg
549	WK(9)	" "	240.0	Sec.
550	WK(10)	" "	-40.0	mmHg

ELEMENT NO.	MNEMONIC	DEFINITION	CONSTANT OR INITIAL VALUE	UNITS
551	WK(11)	Time(Sec), LBNP Steps	300.0	Sec.
552	WK(12)	" "	-50.0	mmHg
553	WK(13)	" "	360.0	Sec.
554	WK(14)	" "	0.0	mmHg
555	WK(15)	" "	400.0	Sec.
556	WK(16)	" "	0.0	mmHg
557	WK(17)	" "	0.0	Sec.
558	WK(18)	" "	0.0	mmHg
559	WK(19)	" "	0.0	Sec.
560	WK(20)	Finish Time	401.0	Sec.
561	HR	Heart Rate	Calculated	Beats/Min
562	SV	Stroke Volume	"	Liters
563	CO	Cardiac Output	"	Liters/Min
564	RT	Total Peripheral Resistance	"	mmHg/L/Min
565		Not Used	-	-
566		" "	-	-
567	PSYS	Systolic Blood Pressure	0.0	mmHg
568	PDYS	Diastolic Blood Pressure	0.0	"
569		Not Used		-
570		" "	-	-
571		" "		
572	PIAB	Intra-Abdominal Pressure	0.0	mmHg
573	PITH	Intra-Thoracic Pressure	-1.5	"
574		Not Used	-	-
575	THETA	Body Angle Relative to Horizontal	0.0	Degrees
576	SF	Contraction Strength Factor	0.48	-
577	TTOT	Heart Period	0.833	Sec.
578	TAS	Period of Systole	0.19	Sec.
579	TVS	Period of Diastole	0.36	Sec.
580		Not Used		-
581		" "	-	-
582	GNEW	Gain Constant	-0.015	-
583	PEXIN	Pressure Set Point	88.0	mmHg
584		Not Used	-	-
(585)- 597		Not Used	-	-
598	WAVEFM	Output Option	340.0	Sec.
599	DPRT	Print Interval	10.0	Sec.
600	VLEG	Total Leg Blood Volume	0.0	ml

```
      COMMON/STATE/X(50),XDOT(50)
     2/STATE/QRA,QRV,QLA,QLV,QPA,QPC,QPV,QAA,QARC,QLAA,QUTA,QLTA,QUABA,
     3QLABA,QCILL,QLGSA,QLGAR,QLGCAP,QLGVE,QLGSV,QFEV,QABVC,QTHVC,QSPVC,
     4QLOC,QUPC,QHCAP,QHSV,QJV,QCOR,QCSMA,QIMA,QCSMV,QPOV,QIMV,
     5QRENA,QRALE,QRENV,QRET,QD(10),QSKB
     6/STATE/CRA,CRV,CLA,CLV,CPA,CPC,CPV,CAA,CARC,CLAA,CUTA,CLTA,CUABA,
     7CLABA,CCILL,CLGSA,CLGAR,CLGVE,CLGSV,CFEV,CABVC,CTHVC,CSPVC,
     8CLOC,CUPC,CHSV,CJV,CCSMV,CIMV,CPOV,
     9CRENA,CRENV,CD(18)
     A/STATE/PRA,PRV,PLA,PLV,PPA,PPC,PPV,PAA,PARC,PLAA,PUTA,PLTA,PUABA,
     BPLABA,PCILL,PLGSA,PLGAR,PLGVE,PLGSV,PFEV,PABVC,PTHVC,PSPVC,
     CPLOC,PUPC,PHSV,PJV,PCSMV,PIMV,PPOV,
     DPRENA,PRENV,PD(16),PM,PMC
      COMMON/STATE/
     ERRA,RRV,RMV,RAV,RPA,RPC,RPV,RARC,RLAA,RUTA,RLTA,RUABA,
     FRLABA,RCILL,RLGSA,RLGAR,RLGCAP,RLGVE,RLGSV,RFEV,RABVC,
     GRTHVC,RSPVC,RLOC,RUPC,RHCAP,RHSV,RJV,RCOR,RCSMA,RIMA,RCSMV,
     HRPOV,RIMV,RRENA,RRALE,RREFF,RRENV,RD(11),RSKB
     I/STATE/FLPA,FLAA,FLARC,FLLAA,FLUTA,FLLTA,FLUABA,
     JFLLABA,FLCILL,FLCSMA,FLIMA,FLRENA,FLDM(8)
     K/STATE/V(50),VU(50),PG(34),PEXT(32),E(4)
     *,PRN,ABIAS,TBIAS,TTHAZ,TMODEL,SPACE(2),ECBV,PTIS,BSLG
     L,Z(40),WK(20),HR,SV,CO,RT,PEX,W,PSYS,PDYS,FREQ
     M,VO2DOT,AVD,PIAB,PITH,PMP,THETA,SF
     N,TTOT,TAS,TVS,C1,C2,GNE*,PEXIN,TR
     *,DUMMY(13),WAVEFM,DPRT,VLEG
      COMMON/PLTBUF/NBUF,XBUF(181),YBUF(181,8),NW(8),KSTOPP,PGD(2)
      COMMON/PNTBUF/N(8),KPLT
      COMMON /WAVE/ NBUFW,NWV(8),XBUFW(181),YBUFW(181,8)
      DIMENSION NV(8),PGDT(2)
      DATA NV/204,224,208,211,212,214,215,231/
      DATA KQ/'N'/,PGD/'    ',    '/,PGDT/'WAVE','FORM'/
      CALL XIO(T)
           ****LONG TERM VASCULAR STRESS RELAXATION****
           ****INPUT BLOOD SHIFT PROTOCAL IN DATA BVS****
      DAY=DUMMY(1)
      DIMENSION BVS(200)
      DATA BVS/0.,0.,5.,236.,9.,266.,12.,355.,16.,398.,19.,383.,
     &22.,443.,25.,413.,184*0./
      IF(BVS(3).EQ.0..OR.DAY.EQ.0.)GO TO 75
   71 DO 72 I=1,99,2
      BVSD=(BVS(I+3)-BVS(I+1))*(TD-BVS(I))/(BVS(I+2)-BVS(I))
     &+BVS(I+1)
      IF(TD.LE.BVS(I+2).AND.TD.GE.BVS(I))GO TO 73
   72 CONTINUE
   73 BDOT=(BVSD-BVSN)/14.
      BVSN=BVSN+.1*BDOT
      TD=.1+TD
      IF(TD.LT.DAY)GO TO 71
      VUOT=VU(18)+VU(19)+VU(20)
      DPCT=-(0.592*BVSN)/VUOT+1.
      VU(18)=DPCT*VU(18)
      VU(19)=DPCT*VU(19)
      VU(20)=DPCT*VU(20)
      BSLG=BVSD
   75 CONTINUE
      CALL CONTRL(T)
```

```
      CALL CVS(T)
    1 CALL ALGO(T)
      IF (T.GT.TTHAZ) THETA=0.
      IF (T.LT.WK(20)) GO TO 1
      IF (KPLT.NE.0) GO TO 4
      WRITE (6,2)
    2 FORMAT ('0DO YOU WISH TO PLOT BUFFERED OUTPUT DATA? (Y/N)')
      READ (5,3) K
    3 FORMAT (1A1)
      IF (K.EQ.KQ) GO TO 40
    4 KSTOPP=1
      CALL PLOT
      CALL NEWPAG
      WRITE (6,5)
    5 FORMAT ('0DO YOU WISH TO PRINT TABULAR OUTPUT DATA? (Y/N)')
      READ (5,3) K
      IF (K.EQ.KQ) GO TO 40
      CALL NEWPAG
      WRITE (6,10) NW,(N(I),I=1,8)
   10 FORMAT(///'    SECS',8(2X,A6)/'     599',8I8/'  *****',
     *  8('    *****'))
      DO 20 I=1,NBUF
      LP=XBUF(I)
      PT=LP
      IF (MOD(I,30).EQ.0) CALL PAGE3
   20 WRITE (6,30) PT,(YBUF(I,J),J=1,8)
   30 FORMAT (F7.1,8F8.3)
   40 WRITE (6,45)
   45 FORMAT('0DO YOU WISH TO PLOT PRESSURE WAVEFORM DATA? (Y/N)')
      READ (5,3) K
      IF (K.EQ.KQ) CALL EXIT
      NBUF=NBUFW
      PGD(1)=PGDT(1)
      PGD(2)=PGDT(2)
      DO 50 I=1,8
      NW(I)=NWV(I)
      N(I)=NV(I)
      DO 50 J=1,NBUFW
      IF (I.EQ.1) XBUF(J)=XBUFW(J)
      YBUF(J,I)=YBUFW(J,I)
   50 CONTINUE
      NWK20=XBUFW(NBUFW)+1.5
      WK(20)=NWK20
      GO TO 4
      END
```

```
      SUBROUTINE CVS(T)
C               GE CARDIOVASCULAR LBNP MODEL
C                          CONTROLLED SYSTEM
      COMMON/STATE/X(50),XDOT(50)
     2/STATE/QRA,QRV,QLA,QLV,QPA,QPC,QPV,QAA,QARC,QLAA,QUTA,QLTA,QUABA,
     3QLABA,QCILL,QLGSA,QLGAR,QLGCAP,QLGVE,QLGSV,QFEV,QABVC,QTHVC,QSPVC,
     4QLOC,QUPC,QHCAP,QHSV,QJV,QCOR,QCSMA,QIMA,QCSMV,QPOV,QIMV,
     5QRENA,QRALE,QRENV,QRET,QD(10),QSKB
     6/STATE/CRA,CRV,CLA,CLV,CPA,CPC,CPV,CAA,CARC,CLAA,CUTA,CLTA,CUABA,
     7CLABA,CCILL,CLGSA,CLGAR,CLGVE,CLGSV,CFEV,CABVC,CTHVC,CSPVC,
     8CLOC,CUPC,CHSV,CJV,CCSMV,CIMV,CPOV,
     9CRENA,CRENV,CD(18)
```

```
      A/STATE/PRA,PRV,PLA,PLV,PPA,PPC,PPV,PAA,PARC,PLAA,PUTA,PLTA,PUABA,
      BPLABA,PCILL,PLGSA,PLGAR,PLGVE,PLGSV,PFEV,PABVC,PTHVC,PSPVC,
      CPLOC,PUPC,PHSV,PJV,PCSMV,PIMV,PPOV,
      DPRENA,PRENV,PD(16),PM,PMC
       COMMON/STATE/
      ERRA,RRV,RMV,RAV,RPA,RPC,RPV,RARC,RLAA,RUTA,RLTA,RUABA,
      FRLABA,RCILL,RLGSA,RLGAR,RLGCAP,RLGVE,RLGSV,RFEV,RABVC,
      GRTHVC,RSPVC,RLOC,RUPC,RHCAP,RHSV,RJV,RCOR,RCSMA,RIMA,RCSMV,
      HRPOV,RIMV,RRENA,RRALE,RREFF,RRENV,RD(11),RSKB
      I/STATE/FLPA,FLAA,FLARC,FLLAA,FLUTA,FLLTA,FLUABA,
      JFLLABA,FLCILL,FLCSMA,FLIMA,FLRENA,FLDM(8)
      K/STATE/V(50),VU(50),PG(34),PEXT(32),E(4)
      *,PRN,ABIAS,TBIAS,TTHAZ,TMODEL,SPACE(2),ECBV,PTIS,BSLG
      L,Z(40),WK(20),HR,SV,CO,RT,PEX,W,PSYS,PDYS,FREQ
      M,VO2DOT,AVD,PIAB,PITH,PMP,THETA,SF
      N,TTOT,TAS,TVS,C1,C2,GNEW,PEXIN,TR
      *,DUMMY(13),WAVEFM,DPRT,VLEG
       DIMENSION PRS(1),CMP(32),RSO(50),FINR(12)
       EQUIVALENCE (PRS,PRA),(CMP(1),CRA),(RSO(1),RRA),(FINR(1),FLPA)
C              T IS ELAPSED TIME
C              TT IS A CLOCK FOR ONE BEAT
       TT=T-TSVE
       IF (TT-TTOT) 1002,1001,1001
 1001  TSVE=T
C*****
       CO=X(33)/TTOT*.06
       X(33)=0.0
       PM=X(10)/TTOT
       X(10)=0.0
       PMC=X(13)/TTOT
       X(13)=0.0
       PD(1)=X(37)/TTOT
       X(37)=0.0
       SV=TTOT/60.*CO
       RT=PD(1)/CO
       IF(T.GT.35.)GO TO 993
       DIFF=-V(50)+V(49)
       X(18)=X(18)+DIFF*0.6
       X(19)=X(19)+DIFF*0.4
  993  CONTINUE
       PSYS=SYS
       PDYS=DYS
       CALL XIO(T)
  110  CALL CONTRL(T)
       TEMP=TEMP+0.2
       IF (TEMP-T) 110,111,111
  111  CONTINUE
       SYS=0.0
       DYS=1000.
       TTOT=60./HR
       TAS=0.10+0.09*TTOT
       TVS=0.16+0.20*TTOT
C***** LBNP *****
       IF (T.LT.41. .OR. T.GT.43.) GO TO 20
       DO 10 I=1,32
    10 PG(I)=SIN(THETA/57.2958)*Z(I)*1.05*980./1332.
    20 CONTINUE
```

```
      IF (TMODEL.GT.0.) GO TO 26
      DO 25 I=1,18,2
      IF (WK(I).LT.0.) GO TO 30
      IF (T.GT.WK(I)) PLBNP=-WK(I+1)
   25 CONTINUE
      GO TO 30
C  26 IF (ABS(THETA).LT.1.E-5 .OR. T.LT.40.) GO TO 30
   26 IF (ABS(THETA).GT.1.E-5) TILTD=1.
      IF (ABS(THETA).GT.1.E-5) GO TO 30
      IF (TILTD.GT.2.) GO TO 30
      DO 28 I=1,32
   28 PG(I)=0.
      TILTD=3.
   30 CONTINUE
      VLEG=0.
      DO 201 I=15,20
      VLEG=VLEG+V(I)
  201 PEXT(I)=-PLBNP
      VLEG=VLEG-VU(18)-VU(19)-VU(20)
      IF(T.GT.WK(3).OR.BSLG.LT.1.)GO TO 301
      IF(PGBIAS.LT.2.)PGBIAS=2.
      DVL=554.-VLEG-BSLG
      IF(DVL.LT.-120.)PGBIAS=PGBIAS+.2
      IF(DVL.GT.5.)PGBIAS=PGBIAS-.1
      IF(DVL.GT.-120..AND.DVL.LT.-5.)PGBIAS=PGBIAS+.05
  301 CONTINUE
      TEMPV=0.
      DO 16 I=1,32
   16 TEMPV=TEMPV+VU(I)
      ECBV=V(50)-VLEG-TEMPV+VU(18)+VU(19)+VU(20)
     & +VU(15)+VU(16)+VU(17)
C*************
 1002 CONTINUE
C***  FOR WAVEFORM PLOTS, SET WAVEFM*598* TO TIME DESIRED
      COMMON /WAVE/ NBUFW,NWV(8),XBUFW(181),YBUFW(181,8)
      DATA NWV/'   PLV  PLOC   PAA  PUTA  PLTA PLABA PCILL PRENA'/
      DATA NBUFW/0/
      IF (WAVEFM.LT.0.5) GO TO 220
      IF (NBUFW.EQ.0) WVPT=WAVEFM-2.
      IF (T.LT.WVPT .OR. T.GT.WAVEFM) GO TO 220
      WVPT=WVPT+0.0115
      NBUFW=NBUFW+1
      IF (NBUFW.GT.181) NBUFW=181
      XBUFW(NBUFW)=T
      YBUFW(NBUFW,1)=PLV
      YBUFW(NBUFW,2)=PLOC
      YBUFW(NBUFW,3)=PAA
      YBUFW(NBUFW,4)=PUTA
      YBUFW(NBUFW,5)=PLTA
      YBUFW(NBUFW,6)=PLABA
      YBUFW(NBUFW,7)=PCILL
      YBUFW(NBUFW,8)=PRENA
  220 CONTINUE
      IF(TT-TAS)1,2,2
    1 SAS=SIN(3.1416*TT/TAS)
      E(1)=0.05+0.05*SAS*SF
      E(3)=0.12+0.14*SAS*SF
```

```
      RSPVC=(20.+SAS*40.)/1332.
      RTHVC=(10.+SAS*20.)/1332.
      GO TO 3
    2 E(1)=0.05
      E(3)=0.12
      RSPVC=.015015
      RTHVC=.0075075
    3 TV=TT-0.1
      IF(TV.LT.0.0)TV=0.0
      IF(TV-TVS)4,5,5
    4 SVS=SIN(3.1416*TV/TVS)
      E(2)=0.0175+.39*SF*SVS
      E(4)=0.02+1.50*SF*SVS
      GO TO 6
    5 E(2)=0.0175
      E(4)=0.02
    6 CONTINUE
      DO 11 I=1,4
   11 CMP(I)=1./E(I)
      IF(X(4).LT.0.0)X(4)=0.0
C               COMPUTE VOLUMES
      V(50)=0.0
      DO 55 I=1,32
      V(I)=VU(I)+X(I)
   55 V(50)=V(50)+V(I)
      V(50)=V(50)-V(9)-V(11)-V(13)-V(10)-VU(18)-VU(19)-VU(20)
      DO 71 I=1,12
   71 PEXT(I)=PITH
      PEXT(22)=PITH
      PEXT(23)=PITH
      DO 72 I=28,32
   72 PEXT(I)=PIAB
      PEXT(14)=PIAB
      PEXT(21)=PIAB
C               COMPUTE PRESSURES
      DO 12 I=1,7
   12 PRS(I)=X(I)/CMP(I)+PEXT(I)
      DO 13 I=15,17
   13 PRS(I)=X(I)/CMP(I)+PEXT(I)
      DO 15 I=18,20
      PRS(I)=X(I)/VU(I)*2.+PEXT(I)+PTIS+PGBIAS-2.
   15 IF(X(I).GT.VU(I))PRS(I)=
     &(X(I)-VU(I))/CMP(I)+PEXT(I)+PTIS+PGBIAS
      DO 14 I=24,32
   14 PRS(I)=X(I)/CMP(I)+PEXT(I)
      PAA=X(8)/CAA+PITH
      PUTA=X(29)/CUTA+PITH
      PLTA=X(12)/CLTA+PITH
      IF(PUTA.GT.SYS)SYS=PUTA
      IF(PUTA.LT.DYS)DYS=PUTA
      PLABA=PIAB-11.826+0.002265*V(14)+0.0097734*V(14)*V(14)
      PLABA=X(14)/CLABA+PIAB
C***  ABDOMINAL VENA CAVA
      PABVC=-5.4996+0.082408*V(21)-0.00033598*V(21)*V(21)
     ,+0.0000045026*V(21)*V(21)*V(21)
      IF (X(21).GT.200. .AND. X(21).LT.350.)
     , PABVC=.34/150.*(X(21)-200.)+1.15
```

```
C*,** THORACIC VENA CAVA
      PTHVC=-5.5006+0.1154*V(22)-0.00065873*V(22)*V(22)
     ,+0.00000236*V(22)*V(22)*V(22)
      IF (X(22).GT.150. .AND. X(22).LT.250.)
     , PTHVC=.3/100. * (X(22)-150.) + 1.16
      PSPVC=-3.4999+0.92409*X(23)-0.042246*X(23)*X(23)
     ,+0.00063485*X(23)*X(23)*X(23)
      PTHVC=PTHVC+PEXT(22)+TBIAS
      PABVC=PABVC+PEXT(21)+ABIAS
      PSPVC=PSPVC+PEXT(23)
      QRA=(PRA-PRV)/RRA
C               HEART MODEL
      IF(PRA.LT.PRV)QRA=0.0
      QRV=X(09)/FLPA
      IF(QRV.LT.0.0)QRV=0.0
      XDOT(09)=PRV-PPA-RRV*QRV
      IF(XDOT(09).LT.0.0.AND.QRV.EQ.0.0)XDOT(09)=0.0
      QLA=(PLA-PLV)/RMV
      IF(PLA.LT.PLV)QLA=0.0
      QLV=X(11)/FLAA
      IF(QLV.LT.0.0)QLV=0.0
      XDOT(11)=PLV-PAA+PG(8)-RAV*QLV
      IF(XDOT(11).LT.0.0.AND.QLV.EQ.0.0)XDOT(11)=0.0
C               PULMONARY CIRCULATION
      QPA=(PPA-PPC)/RPA
      QPC=(PPC-PPV)/RPC
      QPV=(PPV-PLA)/RPV
C               ARTERIAL MODEL
      QUTA=X(34)/FLLTA
      XDOT(34)=PUTA-PLTA+PG(13)-RLTA*QUTA
      QLTA=X(35)/FLLABA
      XDOT(35)=PLTA-PLABA+PG(14)-RLABA*QLTA
      QLABA=(PLABA-PCILL+PG(15))/RCILL
      QAA=X(36)/FLUTA
      XDOT(36)=PAA-PUTA+PG(12)-RUTA*QAA
C               LEGS
      QCILL=(PCILL+PG(16)-PLGSA)/RLGSA
      QLGSA=(PLGSA-PLGAR)/RLGAR
      QLGCAP=(PLGAR-PLGVE)/RLGCAP
      RLGVE=.075075
      IF(QLGVE.LT.0.0)RLGVE=67.567567
      QLGVE=(PLGVE-PLGSV)/RLGVE
      RLGSV=.075075
      IF(QLGSV.LT.0.0)RLGSV=67.567567
      QLGSV=(PLGSV-PG(19)-PFEV)/RLGSV
C               VENOUS MODEL
      RFEV=.021021
      IF(QFEV.LT.0.0)RFEV=67.567567
      QFEV=(PFEV-PG(20)-PABVC)/RFEV
      QABVC=(PABVC-PG(21)-PTHVC)/RABVC
      QTHVC=(PTHVC-PG(22)-PRA)/RTHVC
      QSPVC=(PSPVC-PG(23)-PRA)/RSPVC
C               HEAD+ARMS
      QLOC=(PAA+PG(24)-PLOC)/RLOC
      QUPC=(PLOC-PUPC)/RUPC
      QHCAP=(PUPC-PHSV)/RHCAP
      QHSV=(PHSV-PJV)/RHSV
```

```
      RJV=.004301
      IF(QJV.LT.0.0)RJV=67.567567
      QJV=(PJV-PG(27)-PSPVC)/RJV
C               CORONARY CIRCULATION
      QCOR=(PAA-PRA)/RCOR
C               CONTINUITY FOR VENOUS RETURN
      QRET=QSPVC+QTHVC+QCOR
C               HEPATIC-SPLANCHNIC CIRCULATION
      QCSMA=(PLTA-PCSMV)/RCSMA
      QCSMV=(PCSMV-PPOV)/RCSMV
      QPOV=(PPOV-PTHVC)/RPOV
C               RENAL CIRCULATION
      QRENA=(PLABA-PRENA)/RRENA
      QRALE=(PRENA-PRENV)/(RRALE+RREFF)
      QRENV=(PRENV-PABVC)/RRENV
C               SKELTON,BONE MARROW,AND OTHER
      QSKB=(PLABA-PABVC)/RSKB
C               STATE VARIABLE DERIVATIVES
      XDOT(1)=QRET-QRA
      XDOT(2)=QRA-QRV
      XDOT(3)=QPV-QLA
      XDOT(4)=QLA-QLV
      XDOT(5)=QRV-QPA
      XDOT(6)=QPA-QPC
      XDOT(7)=QPC-QPV
      XDOT(8)=QLV-QAA-QCOR-QLOC
      XDOT(10)=PAA
      XDOT(12)=QUTA-QLTA-QCSMA
      XDOT(14)=QLTA-QLABA-QRENA-QSKB
      XDOT(15)=QLABA-QCILL
      XDOT(16)=QCILL-QLGSA
      XDOT(17)=QLGSA-QLGCAP
      XDOT(18)=QLGCAP-QLGVE
      XDOT(19)=QLGVE-QLGSV
      XDOT(20)=QLGSV-QFEV
      XDOT(21)=QFEV-QABVC+QRENV+QSKB
      XDOT(22)=QABVC+QPOV-QTHVC
      XDOT(23)=QJV-QSPVC
      XDOT(24)=QLOC-QUPC
      XDOT(25)=QUPC-QHCAP
      XDOT(26)=QHCAP-QHSV
      XDOT(27)=QHSV-QJV
      XDOT(28)=QCSMA-QCSMV
      XDOT(29)=QAA-QUTA
      XDOT(30)=QCSMV-QPOV
      XDOT(31)=QRENA-QRALE
      XDOT(32)=QRALE-QRENV
      XDOT(33)=QLV
      XDOT(13)=PLOC
      XDOT(37)=PUTA
      RETURN
      END
      SUBROUTINE CONTRL(T)
      COMMON/STATE/X(50),XDOT(50)
     2/STATE/QRA,QRV,QLA,QLV,QPA,QPC,QPV,QAA,QARC,QLAA,QUTA,QLTA,QUABA,
     3QLABA,QCILL,QLGSA,QLGAR,QLGCAP,QLGVE,QLGSV,QFEV,QABVC,QTHVC,QSPVC,
     4QLOC,QUPC,QHCAP,QHSV,QJV,QCOR,QCSMA,QIMA,QCSMV,QPOV,QIMV,
```

```
     5QRENA,QRALE,QRENV,QRET,QD(10),QSKB
     6/STATE/CRA,CRV,CLA,CLV,CPA,CPC,CPV,CAA,CARC,CLAA,CUTA,CLTA,CUABA,
     7CLABA,CCILL,CLGSA,CLGAR,CLGVE,CLGSV,CFEV,CABVC,CTHVC,CSPVC,
     8CLOC,CUPC,CHSV,CJV,CCSMV,CIMV,CPOV,
     9CRENA,CRENV,CD(18)
     A/STATE/PRA,PRV,PLA,PLV,PPA,PPC,PPV,PAA,PARC,PLAA,PUTA,PLTA,PUABA,
     BPLABA,PCILL,PLGSA,PLGAR,PLGVE,PLGSV,PFEV,PABVC,PTHVC,PSPVC,
     CPLOC,PUPC,PHSV,PJV,PCSMV,PIMV,PPOV,
     DPRENA,PRENV,PD(16),PM,PMC
      COMMON/STATE/
     ERRA,RRV,RMV,RAV,RPA,RPC,RPV,RARC,RLAA,RUTA,RLTA,RUABA,
     FRLABA,RCILL,RLGSA,RLGAR,RLGCAP,RLGVE,RLGSV,RFEV,RABVC,
     GRTHVC,RSPVC,RLOC,RUPC,RHCAP,RHSV,RJV,RCOR,RCSMA,RIMA,RCSMV,
     HRPOV,RIMV,RRENA,RRALE,RREFF,RRENV,RD(11),RSKB
     I/STATE/FLPA,FLAA,FLARC,FLLAA,FLUTA,FLLTA,FLUABA,
     JFLLABA,FLCILL,FLCSMA,FLIMA,FLRENA,FLOM(8)
     K/STATE/V(50),VU(50),PG(34),PEXT(32),E(4)
     *,PRN,ABIAS,TBIAS,TTHAZ,TMODEL,SPACE(2),ECLV,PTIS,BSLG
     L,Z(40),WK(20),HR,SV,CO,RT,PEX,W,PSYS,PDYS,FREQ
     M,VO2DOT,AVD,PIAB,PITH,PMP,THETA,SF
     N,TTOT,TAS,TVS,C1,C2,GNEW,PEXIN,TR
     *,DUMMY(13),WAVEFM,DPRT,VLEG
C              CONTROLLED RESISTANCES
      RRALE=600./1332.
      RSKB=6860./1332.
      RCSMA=10230./1332.
      RHCAP=4570./1332.
      RCOR=20500./1332.
      RLGAR=7250./1332.
      RREFF=2.744
      IF (T.LT.5.) SFS=SF
      IF (THETA.GT.45. .AND. T.GT.40.) GO TO 600
      RCSMA=1.87
      RLGAR=6000./1332.
      GO TO 610
  600 RREFF=3.75
      SF=.64
  610 CONTINUE
      IF (ABS(THETA).LT.1.E-5) SF=SFS
C                                   PRESSURE REFERENCE FUNCTION PR
      E3=E2
      E2=E0
      E0=EN
      EN=PRN-PM/2.-PMC/2.
      ER=(E3+E2+E0+EN)/4.
      GAIN=GNEW
      PAVG=PD(1)
      IF (PAVG.LT.95. .AND. PAVG.GT.89.) GAIN=1.55*GNEW
      IF (PAVG.LE.89.) GAIN=4.1*GNEW
      DDP=0.533+(ER*GAIN)
      IF(DDP.LT.0.0)DDP=0.0
      TOT=0.300+DDP
      HR=60./TOT
      RETURN
      END
-------------------------------------------------------------------------------
      SUBROUTINE ALGO(T)
C              INTEGRATION ALGORITHM
```

```
      COMMON /STATE/ X(50),XDOT(50)
      DIMENSION XDS(50)
      IF(H)1,1,2
    2 DO 3 I=1,NOSV
    3 XDS(I)=XDOT(I)
      T=T+H
      CALL CVS(T)
      DO 4 I=1,NOSV
    4   X(I)=H/2.*(XDOT(I)+XDS(I))+X(I)
   10 RETURN
    1 CONTINUE
      NOSV=38
      H=.002
      GO TO 10
      END
      SUBROUTINE XIO(T)
      COMMON/STATE/X(600)
      COMMON/PLTBUF/NBUF,XBUF(181),YBUF(181,8),NW(8),KSTOPP
      COMMON/PNTBUF/N(8),KPLT
      DIMENSION A(8,6)
      DATA NBUF/1/
      DATA KY,INIT,NWB,NWTL/1HN,0,6H      ,6H  TILT/
      DATA NW/'    HR','    CO','    SV','    PM',
     *    '  SYST','  DIAS','  LBNP','  LEGV'/
      DATA N/561,563,562,249,567,568,469,600/
      IF (INIT.GT.0) GO TO 200
      INIT=1
      MDN=0
      CALL CDATE(MD)
      CALL CTIME(MT)
      WRITE(6,5)MD,MT,MDN
    5 FORMAT(/'   CARDIOVASCULAR LBNP/TILT MODEL',6X,A6,' AT ',A6/
     * '   REFER TO GE-AGS USER GUIDE TIR 741-MED-4008'//
     * '   **** MODEL INCLUDES MOD NUMBER',I3//
     * '/TO SIMULATE TILT EXPERIMENT ENTER 1.')
      READ (5,6) X(495)
    6 FORMAT (F5.0)
      WRITE (6,7)
    7 FORMAT('0DO YOU WANT GRAPHIC OUTPUT? (Y/N)')
      READ (5,20) K
      IF (K.NE.KY) KPLT=1
    9 WRITE (  6,10)
   10 FORMAT('0DO YOU WISH TO CHANGE INITIALIZED DATA? (Y/N)')
      READ (  5,20) K
   20 FORMAT(1A1)
      IF (K.EQ.KY) GO TO 60
      WRITE (  6,30)
   30 FORMAT('0PLEASE ENTER INDEX(1-600), VALUE, CR: (I3,E12.6)')
      GO TO 40
   35 WRITE (6,86)
   40 READ (5,50,ERR=35) I,VALNEW
   50 FORMAT(I3,E12.6)
      WRITE (6,55) I,VALNEW
   55 FORMAT(4X,3H***,I4,F10.4)
      IF (I.LT.1 .OR. I.GT.600) GO TO 60
      X(I) = VALNEW
      GO TO 40
```

```
   60 WRITE (  6,70)
   70 FORMAT('0DO YOU WISH TO MODIFY THE OUTPUT LIST?.(Y/N)')
      READ (  5,20) K
      IF (K.EQ.KY) GO TO 200
      WRITE (  6,80)
   80 FORMAT ('0PLEASE ENTER POSITION(2-9), INDEX(1-600), CR: (I1,I4)')
      GO TO 90
   85 WRITE (6,86)
   86 FORMAT (' *READ ERROR*')
   90 READ (5,100,ERR=85) IP,I
  100 FORMAT(I1,I4)
      WRITE (6,101) IP,I
  101 FORMAT(4X,3H***,I2,I4)
      IF (IP.EQ.0) GO TO 200
      IF (IP.EQ.1) GO TO 9
      IF (IP.LT.2 .OR. IP.GT.9) GO TO 90
      IF (I.LT.1 .OR. I.GT.600) GO TO 90
      GO TO (90,102,103,104,105,106,107,108,109),IP
  102 N(1)=I
      NW(1)=NWB
      GO TO 90
  103 N(2)=I
      NW(2)=NWB
      GO TO 90
  104 N(3)=I
      NW(3)=NWB
      GO TO 90
  105 N(4)=I
      NW(4)=NWB
      GO TO 90
  106 N(5)=I
      NW(5)=NWB
      GO TO 90
  107 N(6)=I
      NW(6)=NWB
      GO TO 90
  108 N(7)=I
      NW(7)=NWB
      GO TO 90
  109 N(8)=I
      NW(8)=NWB
      GO TO 90
  200 CONTINUE
      IF (T.GT.0.001) GO TO 215
      IF (X(495).LT.0.5) GO TO 210
      IF (N(7).NE.469) GO TO 210
      NW(7)=NWTL
      N(7)=575
  210 WRITE (6,205) NW,N
  205 FORMAT(///'   SECS',8(2X,A6)/'     599',8(6/'  *****',
     *  8('    *****'))
  215 DO 220 I=1,8
      K=N(I)
      A(I,5)=X(K)
  220 A(I,6)=(A(I,1)+A(I,2)+A(I,3)+A(I,4)+A(I,5))/5.0
      IF (N(7).EQ.575 .AND. T.LT.41.) A(7,5)=0.
C     WRITE(6,300)T,(A(I,5),I=1,8)
```

```
      IF ((T-PT).LT.1.1 .OR. AMOD(T,ABS(X(599))).GT.1.) GO TO 310
      IF (NBUF.GT.1) GO TO 225
      XBUF(1)=0.
      DO 224 I=1,8
  224 YBUF(1,I)=A(I,6)
  225 NBUF=NBUF+1
      IF (NBUF.GT.181) NBUF=181
      XBUF(NBUF)=T
      DO 230 I=1,8
  230 YBUF(NBUF,I)=A(I,5)
      IF (KPLT.GT.0) CALL PLOT
      LP=T
      PT=LP
      IF (KPLT.GT.0) GO TO 310
      WRITE(6,300)PT,(A(I,5),I=1,8)
  300 FORMAT (F7.1,8F8.3)
      IF (X(599).LT.0.) WRITE (6,305) (X(I),I=1,32)
  305 FORMAT (7X,8F8.3)
  310 DO 320 J=1,4
      DO 320 I=1,8
  320 A(I,J)=A(I,J+1)
      RETURN
      END
      BLOCK DATA
      COMMON/STATE/A(100)
      COMMON/STATE/B(50)
      COMMON/STATE/C(50)
      COMMON/STATE/D(50)
      COMMON/STATE/E(50)
      COMMON/STATE/F(20)
      COMMON/STATE/G(280)
C*** STATE
      DATA A/89.9,215.8,38.7,218.0,7.7,10.6,27.4,23.9,0.,0.,          1- 10
     1 0.,23.6,0.,16.2,62.3,62.4,4.1,126.0,205.,2.5,                  11- 20
     2 355.2,253.5,36.4,23.5,31.2,63.4,3.1,254.2,30.,120.7,           21- 30
     3 17.1,43.7,5*0.,0.0,12*0.,50*0./                                31-100
C*** FLOW
      DATA B/50*0./                                                  101-150
C*** COMP
      DATA C/4*0.,1.2,1.7,5.3,.3,2*0.,2*.4,0,.,.21,2*,8,.3,3.956,3.14,.2, 151-170
     1 3*0.,.3,.3996,5.3,.9058,9.59,1.505,6.047,                     171-180
     2 .2224,2.517,5*0.,.3,12*0./                                    181-200
C*** PRES
      DATA D/48*0.,90.,90./                                          201-250
C*** RES
      DATA E/3*.007508,.008634,.01502,.05255,.015022,2*0.,.040000,   251-260
     1 ,040000,0,,.030000,.030,.03003,4.505,.4505,.07508,.07508,.02102, 261-270
     2.00738,.007508,.01502,.02252,.03378,3.431,.3754,.004302,15.39,2.35 271-280
     3 ,34.5345,.2252,.5255,.3003,.01502,.45045,2.744,.6494,0.,0.,    281-290
     4 9*0.,5.15/                                                    291-300
C*** INRT
      DATA F/.0007508,.004,2*0.,.004,.004,0.,.004,.00626,11*0./      301-320
C*** MISC
      DATA G/48*0.,5000.,5000.,30.,0.,30.,0.,85.,15.,400.,61.6,2*0., 321-380
     1 0.,90.5,0.,43.5,5.194,30.,30.,100.,188.,40.,                  381-390
     2 3*0.,50.,50.,509.,28.,562.,0.0,375.,                          391-400
     3 50.,150.,18*0.,                                               401-420
```

```
     * 34*0.,32*0.,4*0.,88.,2.55,3.60,9999.,0.,                    421-495
     * 0.,0.0,0.,2.,0.,7*0.,-7.,2*0.,                              496-510
     4 0.,10.,10.,16.,6.,33.,2*0.,33.,14.,                        511-520
     5 14.,2.,-7.,-14.,0.,0.,-14.,13*0.,                          521-540
     * 0.,0.,60.,- 8.,120.,-16.,180.,-30.,240.,-40.,              541-550
     * 300.,-50.,360.,0.,400.,4*-1.,401.,                         551-560
     6 72.,.09,6.7,5*0.,8.3,0.,                                   561-570
     7 .0550,0.,-1.5,0.,0.0,.48,.833,.19,.36,46.,                 571-580
     8 10.,-.015,88.,14*0.,340.,10.,0./                           581-600
       END

END ONSITE PRINTOUT ON MARCH 27, 1974 AT 08:10:43
DB6-G03432*TPFS(0),PXX(0)
```

Tilt Example

```
   CARDIOVASCULAR LBNP MODEL       250174 AT 130841
   REFER TO GE-AGS USER GUIDE TIR 741-MED-4008

   **** MODEL INCLUDES MOD NUMBER   0

 TO SIMULATE TILT EXPERIMENT ENTER 1.
>1.

 DO YOU WISH TO CHANGE INITIALIZED DATA? (Y/N)
>Y

 PLEASE ENTER INDEX(1-600), VALUE, CR; (I3,E12.6)
>575 70.

    *** 575   70.0000

>
    ***   0     .0000

 DO YOU WISH TO MODIFY THE OUTPUT LIST? (Y/N)
>N
```

SECS	HR	CO	SV	PM	SYST	DIAS	TILT	LEGV
599	561	563	562	249	567	566	575	600
*****	*****	*****	*****	*****	*****	*****	*****	*****
20.0	62.373	6.478	.104	90.362	126.404	72.642	.000	584.595
40.0	62.283	6.473	.104	90.353	126.437	72.603	.000	584.554
60.0	79.380	5.618	.071	89.973	123.011	83.685	70.000	954.659
80.0	80.807	5.546	.069	89.489	124.698	80.234	70.000	988.101
100.0	80.665	5.554	.069	89.520	123.040	81.826	70.000	988.270
120.0	80.478	5.552	.069	89.610	122.596	81.984	70.000	988.156
140.0	80.541	5.551	.069	89.596	122.865	81.803	70.000	988.201

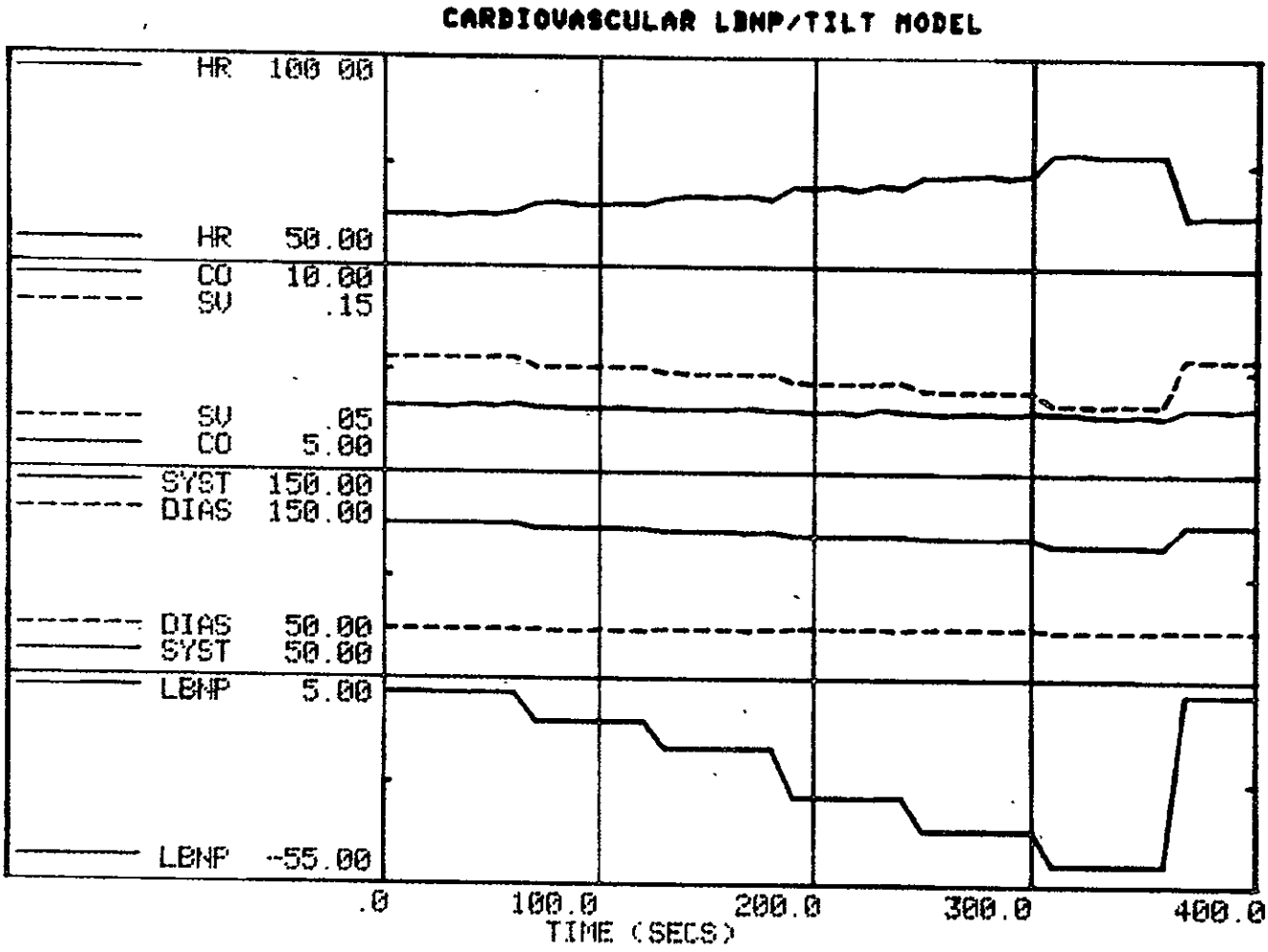
```
@XQT

   CARDIOVASCULAR LBNP/TILT MODEL      260374 AT 151536
   REFER TO GE-AGS USER GUIDE TIR 741-MED-4000

   #### MODEL INCLUDES MOD NUMBER  0

 TO SIMULATE TILT EXPERIMENT ENTER 1.
>
 DO YOU WANT GRAPHIC OUTPUT? (Y/N)
>N
 DO YOU WISH TO CHANGE INITIALIZED DATA? (Y/N)
>Y
 PLEASE ENTER INDEX(1-600), VALUE, CR: (I3,E12.6)
>599 30.
    ### 599   30.0000
>
    ###   0     .0000

 DO YOU WISH TO MODIFY THE OUTPUT LIST? (Y/N)
>N
```

SECS	HR	CO	SV	PM	SYST	DIAS	LBNP	LECV
599	561	563	562	249	567	568	469	600
#####	#####	#####	#####	#####	#####	#####	#####	#####
30.0	61.893	6.513	.105	90.361	125.103	73.294	.000	553.947
60.0	62.005	6.510	.105	90.388	125.000	73.284	.000	553.530
90.0	64.605	6.567	.101	89.592	122.552	72.764	-8.000	625.819
120.0	64.711	6.408	.100	89.659	122.419	72.639	-8.000	626.639
150.0	66.753	6.594	.097	89.359	121.139	72.976	-16.000	698.727
180.0	66.275	6.456	.097	89.291	121.120	73.642	-16.000	698.940
210.0	69.579	6.452	.093	88.781	119.263	73.899	-30.000	826.101
240.0	69.289	6.472	.093	88.694	119.291	73.289	-30.000	825.987
270.0	72.063	6.426	.000	88.284	118.136	73.756	-40.000	917.365
300.0	72.319	6.456	.000	88.339	118.144	73.795	-40.000	917.123
330.0	76.990	6.368	.083	87.381	114.306	72.787	-56.000	1009.134

LBNP EXAMPLE

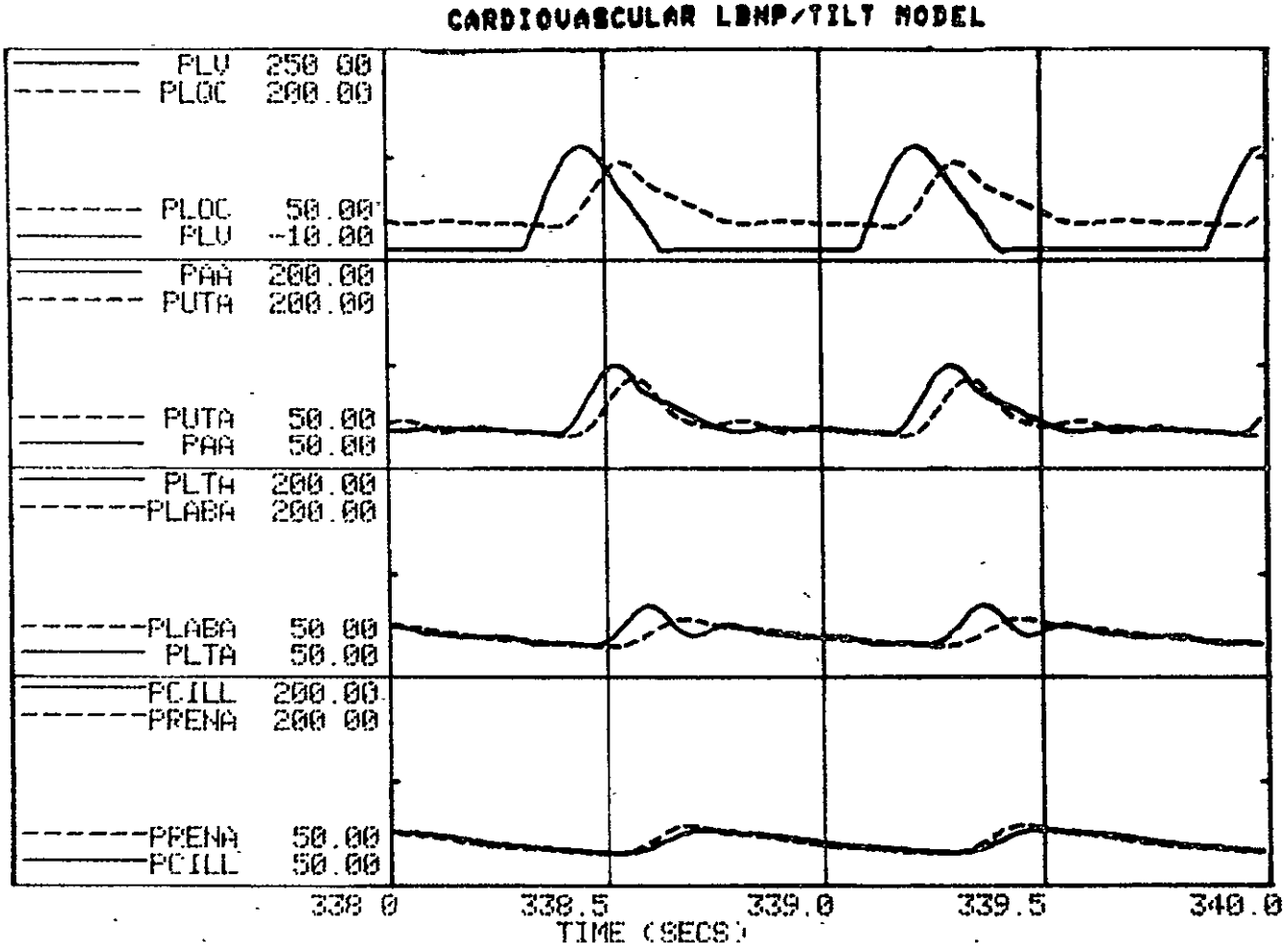
GRAPHIC OUTPUT EXAMPLE

```
@XQT

   CARDIOVASCULAR LBNP/TILT MODEL      270374 AT 132341
   REFER TO GE-AGS USER GUIDE TIR 741-MED-4008

   **** MODEL INCLUDES MOD NUMBER  0

 TO SIMULATE TILT EXPERIMENT ENTER 1.

 DO YOU WANT GRAPHIC OUTPUT? (Y/N)
>Y
 DO YOU WISH TO CHANGE INITIALIZED DATA? (Y/N)
>N
 DO YOU WISH TO MODIFY THE OUTPUT LIST? (Y/N)
>N


   SECS       HR       CO       SV       PM     SYST     DIAS     LBNP     LEGV
    599      561      563      562      249      567      568      469      600
  *****    *****    *****    *****    *****    *****    *****    *****    *****

TYPE SHIFT-OUT (SO) AND RETURN-->

          GRAPHIC OUTPUT(Y,N,S),TIME INTERVALS,STARTX,STOPX,(A2,3F5.0)..
>Y 4.
     HR                  Y SCALE   (A4,8X,F4.0,2F6.0)
 PLOT(Y,N,S) LOC HIGH  LOW    ...
>Y           1.  130.  50.
     CO                  Y SCALE   (A4,8X,F4.0,2F6.0)
 PLOT(Y,N,S) LOC HIGH  LOW    ...
>Y           2.  10.   5.
     SV                  Y SCALE   (A4,8X,F4.0,2F6.0)
 PLOT(Y,N,S) LOC HIGH  LOW    ...
>Y           2.  .15   .05
     PM                  Y SCALE   (A4,8X,F4.0,2F6.0)
 PLOT(Y,N,S) LOC HIGH  LOW    ...
>N
   SYST                  Y SCALE   (A4,8X,F4.0,2F6.0)
 PLOT(Y,N,S) LOC HIGH  LOW    ...
>Y           3.  150   50.
   DIAS                  Y SCALE   (A4,8X,F4.0,2F6.0)
 PLOT(Y,N,S) LOC HIGH  LOW    ...
>Y           3.  150.  50.
   LBNP                  Y SCALE   (A4,8X,F4.0,2F6.0)
 PLOT(Y,N,S) LOC HIGH  LOW    ...
>Y           4.  5.    -55.
   LEGV                  Y SCALE   (A4,8X,F4.0,2F6.0)
 PLOT(Y,N,S) LOC HIGH  LOW    ...
>N
```


CARDIOVASCULAR LBNP/TILT MODEL
HR 100.00
HR 50.00
CO 10.00
SV .15
SV .05
CO 5.00
SYST 150.00
DIAS 150.00
DIAS 50.00
SYST 50.00
LBNP 5.00
LBNP -55.00
.0
100.0
200.0
300.0
400.0
TIME (SECS)

WAVEFORM GRAPHIC OUTPUT EXAMPLE

```
 DO YOU WISH TO PRINT TABULAR OUTPUT DATA? (Y/N)
>N
 DO YOU WISH TO PLOT PRESSURE WAVEFORM DATA? (Y/N)
>Y

 WAVEFORM GRAPHIC OUTPUT(Y,N,S),TIME INTERVALS,STARTX,STOPX,(A2,3F5.0)..
>Y 4:
    PLU                  Y SCALE   (A4,8X,F4.0,2F6.0)
 PLOT(Y,N,S) LOC HIGH  LOW    ...
>Y           1.  250.  -010.
   PLOC                  Y SCALE   (A4,8X,F4.0,2F6.0)
 PLOT(Y,N,S) LOC HIGH  LOW    ...
>Y           1.  200.  50.
    PAA                  Y SCALE   (A4,8X,F4.0,2F6.0)
 PLOT(Y,N,S) LOC HIGH  LOW    ...
>Y           2.  200.  50.
   PUTA                  Y SCALE   (A4,8X,F4.0,2F6.0)
 PLOT(Y,N,S) LOC HIGH  LOW    ...
>Y           2.  200.  50.
   PLTA                  Y SCALE   (A4,8X,F4.0,2F6.0)
 PLOT(Y,N,S) LOC HIGH  LOW    ...
>Y           3.  200.  50.
  PLABA                  Y SCALE   (A4,8X,F4.0,2F6.0)
 PLOT(Y,N,S) LOC HIGH  LOW    ...
>Y           3.  200.  50.
  PCILL                  Y SCALE   (A4,8X,F4.0,2F6.0)
 PLOT(Y,N,S) LOC HIGH  LOW    ...
>Y           4.  200.  50.
  PRENA                  Y SCALE   (A4,8X,F4.0,2F6.0)
 PLOT(Y,N,S) LOC HIGH  LOW    ...
>Y           4.  200.  50.
```


CARDIOVASCULAR LBNP/TILT MODEL
PLV 250.00
PLOC 200.00
PLOC 50.00
PLV -10.00
PAA 200.00
PUTA 200.00
PUTA 50.00
PAA 50.00
PLTA 200.00
PLABA 200.00
PLABA 50.00
PLTA 50.00
PCILL 200.00
PRENA 200.00
PRENA 50.00
PCILL 50.00
338.0
338.5
339.0
339.5
340.0
TIME (SECS)